PROGRESS REPORT, 1957-58

COOPERATIVE SNOW MANAGEMENT RESEARCH

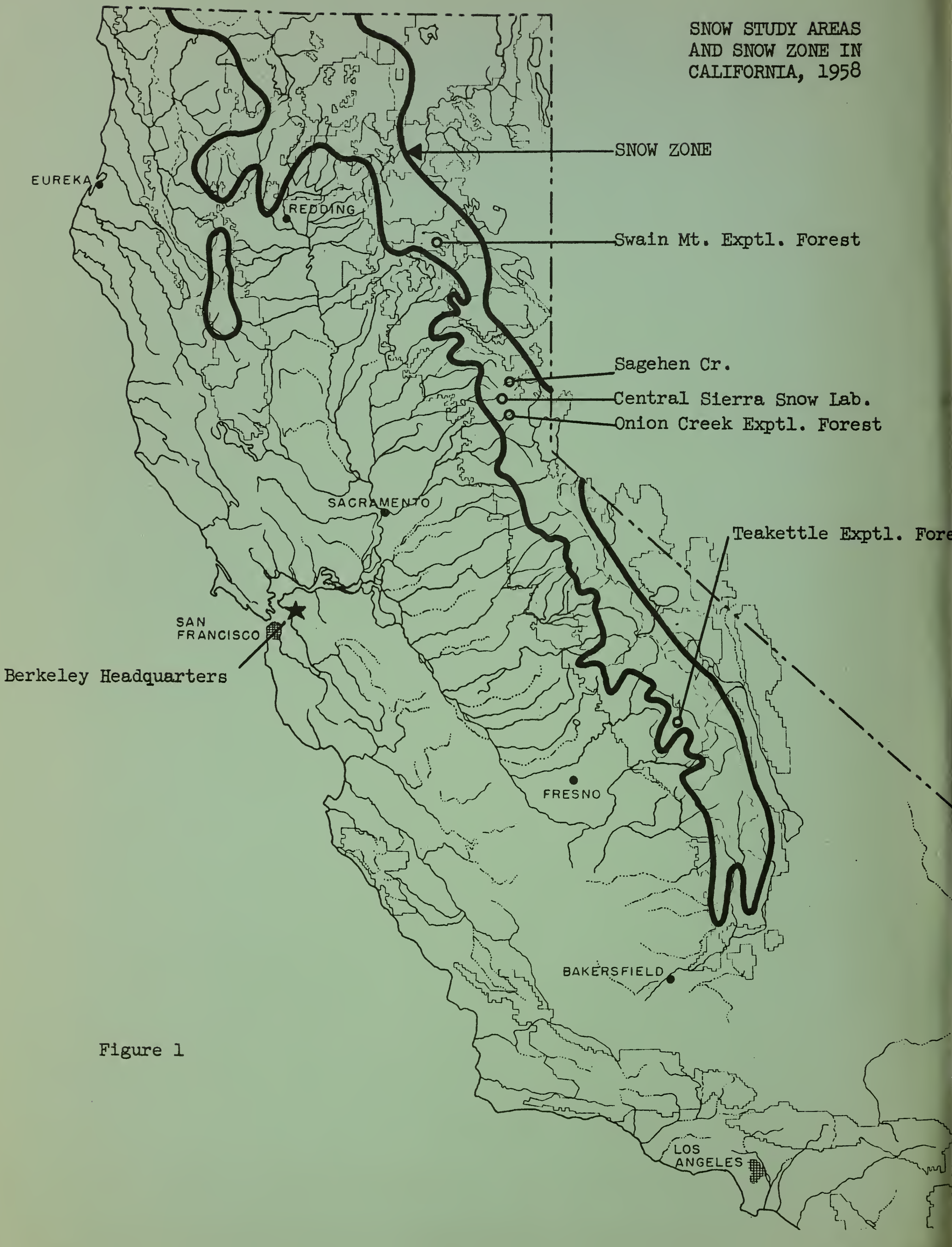

SNOW STUDY AREAS
AND SNOW ZONE IN
CALIFORNIA, 1958
SNOW ZONE
EUREKA
REDDING
Swain Mt. Exptl. Forest
Sagehen Cr.
Central Sierra Snow Lab.
Onion Creek Exptl. Forest
SACRAMENTO
Teakettle Exptl. Fore
SAN
FRANCISCO
Berkeley Headquarters
FRESNO
BAKERSFIELD
LOS
ANGELES

Figure 1

June 30, 1958

PROGRESS REPORT, 1957-58

CALIFORNIA COOPERATIVE SNOW MANAGEMENT RESEARCH

by

Henry W. Anderson, Snow Research Leader,
Division of Watershed Management Research

U. S. Dep't. of Agriculture, Forest Service,
California Forest and Range Experiment Station

in cooperation with

State of California
Department of Water Resources

CONTENTS

INDEX

INDEX

SUMMARY

In July 1956, the Forest Service and the State of California started research aimed at improving California's water yield through management of land in the snowpack zone. By early 1958, 18 separate studies had been set up. This report describes these studies and summarizes progress in 1957 and early 1958,

The California Forest and Range Experiment Station of the Forest Service conducts the research in cooperation with the Department of Water Resources of the State of California. Other agencies are lending a hand: The Pacific Gas and Electric Company, the Weather Bureau, and the Department of Zoology of the University of California. The Station, in turn, is furnishing services and information to these agencies and several others: The State Flood Forecasting Center, the State Cooperative Snow Surveys, and the State Department of Health.

Our staff of 10 technicians is working in the headwaters of five major California river basins. Of the 18 studies underway, 7 are new in 1957-58. The studies are of 4 general kinds: Inventories of present conditions of water yield, land condition, and soil; studies of basic meteorology and snow; development of methods of improving water yield and controlling sediment; and pilot tests of selected methods on experimental watersheds for their effects on streamflow and sedimentation.

This year we were blessed with the "year of the big snow", giving to the research program an essential extreme. Snow depth reached 19 feet on the level at the laboratory headquarters near Donner Summit, and over 36 feet at some parts of outlying courses. Thanks to extraordinary effort, field crews managed to stay on top of the snow, and essentially complete records were obtained.

Plans for the coming year are to concentrate on the studies now under way. Financing is such that progress should be rapid. The State's contribution for the research is $63,000 per year. The U. S. Forest Service is matching this amount.

As rapidly as possible the results of the studies are being reported and published. Nine technical papers were published this year. Nine other papers were presented at technical meetings and are being submitted for publication. Reprints of published papers are available, and other information is available upon request. To make this information more accessible, a detailed index has been included as part of this report.

INTRODUCTION

Snow studies are underway in California to develop and test methods of managing the snow zone for improved water yield. The studies are being made by the California Forest and Range Experiment Station of the U. S. Forest Service with the cooperation of the Department of Water Resources of the State of California.

The snow zone in California lies mostly on the west side of the Sierra Nevada and in the Cascade Ranges, roughly above 5,000 feet in elevation in the southern Sierra and above 3,500 feet in the northern Sierra and Cascade (figure 1). It is the area where more than half of the annual streamflow is yielded April 1 to September 30. The snow zone covers about 12 million acres, or only 12 percent of the state, yet it yields about 50 percent of the State's total streamflow. About 9 million acres of this zone are classed as commercial forest; they contribute about 40 percent of the State's water yield. Water yielded by melt of the snow pack is important not only because it is a large amount, but also because it is high in quality and is the principal water that feeds streams long after the rains have stopped.

Timber stands in the snow pack zone are still largely uncut, but logging is moving upward; it is only a matter of time until these high elevation commercial forests will be cut. We must learn how to cut forests and manage other land in this zone in ways that will exert control over water releases--to guard against deterioration of water supplies originating there and to improve water yield.

HOW CAN WE IMPROVE WATER YIELD?

Water yield could be improved if we can develop ways of accomplishing one or more of these objectives:

1. Increase total streamflow in all years, and especially in dry years.

2. Improve the timing of streamflow, by delaying snow melt and yielding more water in late spring and summer.

3. Maintain or improve water quality.

4. Minimize local floods and reduce sedimentation damages.

In developing methods that will improve water yield, we need to be able to predict the effects on water yield of wide extremes in management practice. Since tomorrow's demands for water may be completely different from today's, our research must span the possible practices, not just aim at the immediately practical.

KINDS OF STUDIES

This is a report of progress during 1957 and early 1958. Each study, its objective, results so far, and our plans ahead are summarised. Eighteen studies are under way. They are of 4 kinds:

1. Inventories of present conditions of water yield (Study No. 1-10), land condition (Studies No. 1-1, 1-5), and soil erodibility (Study No. 1-18).

2. Studies of basic meteorology and snow (1-6, 1-9).

3. Development of methods of improving water yield and controlling sediment (Studies No. 1-4, 1-7, 1-8, 1-11, 1-13, 1-14, 1-15, 1-16).

4. Pilot tests of selected methods on experimental watersheds for their effects on streamflow and sedimentation (1-2, 1-3, 1-12, 1-17).

Detailed plans of these studies are available for inspection upon request.

THE SIX STUDY AREAS

The general location of each study area is shown in Figure 1. The principal activities at each study area are:

1. Berkeley Headquarters--inventories and analyses.

2. Swain Mountain Experimental Forest (Feather River)--Plot studies of the effects of cutting forests in strips and blocks.

3. Sagehen Creek (Truckee River)--plot and watershed tests to relate the effects of land treatment on flood sedimentation, and fish habitat.

4. Central Sierra Snow Laboratory (Yuba River)--studies of basic meteorology, snow physics, and forest hydrology.

5. Onion Creek Experimental Forest (American River)--plot tests of the effects of conventional logging and brush conversion; calibration for watershed treatment.

6. Teakettle Experimental Forest (Kings River)--calibration of watersheds to test the effects of forest cutting and grazing practices on streamflow and sedimentation.

INDIVIDUAL STUDIES

Inventory of Sierra Hydrologic Characteristics (Study No. 1-1)

We are making an inventory of the land conditions of the Sierra in terms which are expected to have hydrologic meaning--kinds of forests and their densities, sizes of openings and their ground conditions (brush, grass-herb, bare ground, or rock outcrop), and the topographic conditions where each occurs.

Objectives--To be able to answer the questions: What land and water conditions require research? How much land is subject to each treatment? Where will each treatment have the most effect on snow and on water yield?

Methods--We are interpreting aerial photos and topographic maps to obtain the desired information. We are studying 40-acre plots located in each 5-minute intersection of latitude and longitude in the Sierra.

Results--L. G. Richards who is carrying on the project has completed 18 transects, sampling about two-thirds of the Sierra above 5,000 feet elevation. The results are summarized in Table 1, Appendix A.

These first results emphasize:

1. That much of the Sierra is open; over 60 percent is in openings greater than 1 chain in radius (132 feet across).

2. That over 30 percent of these openings is occupied by brush. This information points out

that we must study not only the management of timber areas in the snow zone, but also the management of brush areas for improved water yield.

3. That slopes in the snow zone are mostly gentle; over two-thirds are less than 30 percent, but about one-sixth are steeper than 40 percent.

4. That about two-thirds of the slopes face south or west.

Plans--We intend to complete this inventory for the snow zone of the Sierra by January 1, 1959. We will then know not only the individual characteristics, but the combinations of slopes, forests and elevation which exist in the Sierra, and require research.

Selecting and Testing of Central Sierra Experimental Watersheds (Onion Creek Experimental Watersheds) Study No. 1-2)

As part of our preparation for pilot testing of the "best" methods of improving water yield, we are readying several sets of watersheds. The Onion Creek Experimental Watersheds is one such set.

Objectives--To be able to predict accurately the streamflow and sediment production of several small watersheds, to treat these watersheds in ways expected to affect water yield, and to measure the effects of the treatments on water yield and sedimentation.

Methods--We have selected 5 watersheds in the headwaters of the North Fork of the American River. These Onion Creek watersheds are representative of the snow zone as judged by comparison with the results of the inventory of the Sierra (Table 1, Appendix A). The basins are apparently water-tight, that is, dykes or strata bring all the water yield to the surface for measurement. The streams flowed prennially in the 2 years of check; no large springs appear below the watersheds. The watersheds have suitable sites for small dam construction.

Results--Three small dams and a temporary concrete section with gaging station, were installed in the summer of 1957. One of the small dams is shown in Figure 2. Characteristics of the installations and the watersheds are summarized in Table 2, Appendix A. The reservoirs were designed to have equal trap efficiencies--capacity watershed ratios of 0.5 A.F. per sq. mi. of watershed. The weirs are 120° V-notches, designed to pass the 1955 flood with an additional 1 foot of free board. Maximum discharges for 1957-58 occured May 20, and were 30 cfs for No. 1, 74 cfs for No. 2, and 56.1 cfs for No. 5. The reservoirs were surveyed so that sedimentation could be determined annually. Suspended sediment outflow is measured periodically.

Plans--We plan to complete the dam in Onion Creek Watershed No. 3 in the summer of 1958 and in No. 7 if suitable rock foundation is found. We plan to gage these watersheds and measure sediment annually for a period of 5 years or more as needed to calibrate them. When the flow and sedimentation for any watershed can be predicted with sufficient accuracy to detect a significant change in flow, then the watershed will be used to test methods expected to improve water yield. For example, in one watershed we will apply everything we know that will increase total water yield; in another watershed we will apply everything that will delay snowmelt and water yield; in a third we will treat each vegetation type in sequence, brush first, meadows next, forest and alpine last, to test their individual effects. In all treatments, concomitant measurements of snow and of water losses will be taken to tell us which treatments were the most effective, where treatments were effective, and why.

The Department of Water Resources is planning to install a gaging station immediately below these experimental watersheds which should serve as an overall check on streamflow.

Streamgaging and Sediment Measurements at Teakettle Experimental Watersheds, Kings River (Study No. 1-3)

This is another set of High Sierra watersheds being calibrated in preparation for evaluation of the effects of forest cutting and grazing on streamflow and sedimentation.

Figure 2.--Onion Creek No. 2 streamgaging station and dam. Typical setup for pilot testing effects of management on streamflow and sedimentation.

Objectives--To be able to predict accurately the streamflow and sediment production of several small watersheds, to treat these watersheds in ways expected to affect water yield, and to measure the effects of the treatments on water yield and sedimentation.

Methods--Five small watersheds with stone masonary dams and gaging weirs, inoperative since 1941, were reactivated in September 1956. Streamflow and sediment deposition and suspended sediment outflow have been measured for the past 2 years.

Results--The characteristics of the watersheds and measurement devices are summarized in Table 2, Appendix A, together with the annual sediment production for water year 1957. Periodic sedimentation for the 17-year period 1938-53 are tabulated in Appendix C, together with an analysis of the variation of trap efficiency of the reservoirs with changing capacity, Sediment production from these watersheds was very low, averaging 0.016 AF/sq.mi./yr. under the virgin condition of old-growth red fir. A small burn of about 5 acres in 1943 in one of the watersheds caused the average sediment rate for the whole watershed to increase markedly (to 0.036 AF/sq.mi./yr.).

Plans--To continue to gage the watersheds and measure sediment deposition annually for a minimum period of 3 more years. To compute streamflow currently so it can be published with only 10 months delay.

Cooperation--The Pacific Gas and Electric Company has generously cooperated by servicing these Teakettle gaging stations during the winter months.

Inventory of Forest Conditions at the Central Sierra Snow Laboratory Snow Courses (Study No. 1-4)

This is one of our studies in which we utilized snow measurements already taken, refined the measurements of the associated forest conditions, and analyzed the data for clues of the forest effects on snow.

Objectives--To develop methods of expressing forest stands as they influence snow accumulation and melt. To test various indexes of forest effects on snow reaching the ground, redistribution of snow, and melt of the snowpack.

Methods--We have analyzed the snow accumulation and melt measurements taken at the Central Sierra Snow Laboratory by the Snow Investigations (Corps of Engineers and Weather Bureau) in the period 1947 to 1951. We related their snow data to a dozen of our forest variables, testing various hypotheses of forest effects on snow. For one study, we made detailed forest cover maps and took photos at 36 snow measurement points in 6 snow courses.

Results--These studies and their results have been reported in several publications 1/. To briefly summarize, we can say that forest variables were improved when we specifically designed them to index the separate effects of forests on solar radiation received at the snow surface, back radiation from trees, and interchange of energy between forest, clouds, and the sky. Many of the forest effects are not linear; forest effects are much better indexed when this is taken into account in the analyses.

Plans--This study is essentially complete. Attention will now be concentrated on analysis of our own data rather than more analyses of the data of the past. A popular version, summarizing the findings to date is planned.

Soil Vegetation Surveys of Castle Creek Laboratory Basin (Study No. 1-5)

Part of the Central Sierra Snow Laboratory is the Castle Creek drainage, a headwaters tributary to the Yuba River. A detailed survey of the soil, vegetation, and timber stands of the 3.96 square mile laboratory basin was made.

Objectives--To serve as a guide in the planning of specific studies on the effects of soil, vegetation, and timber stands on snow accumulation and melt and the yield of water.

1/ Anderson, H. W. "Forest-cover effects on snowpack accumulation and melt, Central Sierra Snow Laboratory." Trans. Amer. Geophys. Union 37 (3): 307-312, 1957 and 38 (1): 116, 1957. (See also references Report 5 and New Manuscript (2).

Methods--The basin was surveyed in September, 1956, using standard soil vegetation survey procedures. Soil and vegetation types were delineated to a 2-1/2 acre minimum acreage. The information has been summarized by two maps and a report by R. E. Nelson 2/.

Results--The results of the study have been used as a basic guide in three studies: 1-11, 1-13, and 1-15.

Plans--The study is complete. Results of this type of survey will be compared to the Sierra Inventory results of Study 1-1. The value and limitations of soil-vegetation surveys as a tool in watershed management in the snow zone will be assayed.

Basic Meteorological and Snow Measurements, Central Sierra Snow Laboratory (Study No. 1-6)

Objectives--To provide continuous measurements at control sites of the physical elements which affect snow management, records against which data from experimental sites may be compared for consistency, and which may be used to fill in intermittent records from field samples of physical elements.

Methods--At the Central Sierra Snow Laboratory headquarters (Station H), in addition to standard meteorological elements, we are recording:

1. Wind speed and direction at the top of the trees, and at three intermediate heights.

2. Radiation including net and hemispherical all-wave and incident and reflected short wave; daily snow depth and water equivalent.

3. Precipitation intensity.

4. Daily maximum and 8:00 a.m. streamflow of the 3.96 square mile Castle Creek.

2/ See reference (4) in the section on Reports.

At the Upper Meadow Station (Station M) air temperature and humidity are recorded and snow is measured weekly. At the Mt. Lincoln Station (Station L), elevation 8,383 feet, wind speed and direction are recorded from 3 anemometers (when they are not iced up), together with temperature and humidity. At the Ridge Station (Station R), elevation 7,500 feet, in Onion Creek, precipitation and snow are measured. At the Onion Creek Station (Station O), elevation 6,200 feet, standard meteorological elements, precipitation, intensity, and snow are measured periodically. All instruments are in and operating.

Results--The meteorological and snow records taken and the status of data processing are shown in Table 3, Appendix A. Daily records for Headquarters Station H, for the period June 30, 1957 to June 30, 1958 are given in Figure 6, Appendix B and monthly summaries are given in Table 4, Appendix A. Daily 8:00 a.m. streamflow for the Castle Creek for the same period is shown in Figure 7, Appendix B. During the melt season, daily discharge averaged 1.1 times the 8:00 a.m. discharge.

Plans--A special microvolt recording system with tape punch-out is under development and is expected to be in by September 1958 at the Headquarters Station. A parallel portable system for measurement of heat flow components at experimental sites in the forest is also under development. We plan to continue all measurements at the Headquarters Station, and to test correlations between this and other stations, dropping out any measurements for which sufficient data have accumulated or correlations are good enough with the Headquarters or long-term Weather Bureau stations.

Cooperation--The Weather Bureau is cooperating in the studies by taking wind direction and velocity measurements for us at their Blue Canyon Station 20 miles west of the Laboratory, at an elevation of 5,000 feet. We, in turn, are supplying daily meteorological, snow, and streamflow data to them which are used in the State Flood Forecasting Service. We are also supplying daily samples of streamflow and of new snowfall to the State Department of Public Health for analysis of radio-activity.

Wind Effects on Snow Accumulation in Forests (Study No. 1-7)

Objectives--To examine in detail the effects of wind speed and direction upon the deposition and later redistri-

bution of snow. Later, the modification of wind speed and direction, and consequent effects on snow accumulation for various forest treatments will be studied.

Methods--Openings in the forest suited for the study have been selected, in connection with the Heat Equivalent and Snow Study. See Study 1-11.

In addition, we have selected 8 special forest openings: 4 each on north and south slopes, of exposed and topographically sheltered sites. Snow accumulation patterns in the openings are being examined in relation to the wind at "free-air" stations. These "free-air" measurements are from exposed sites, at the Laboratory headquarters, at Blue Canyon (through the cooperation of the Weather Bureau), and on top of Mt. Lincoln (mostly with the instruments not cooperating--they ice up!).

Results--We tried treating the anemometers on Mt. Lincoln to prevent icing. A special silicon anti-icing compound (General Electric) delayed icing somewhat, but the anemometer still iced up. Black paint on the anemometer cups was even less effective. Fortunately, the anemometer at the Blue Canyon station furnished good records. Analyses of these showed that wind during snowfall was largely from the south-southwest, confirming analyses reported by Court (6).

Plans--Wind measurements within forest openings will start when our new field-going data logger-punch out system gets operating. This recorder will record in sequency 96 individual instruments. The records are converted to voltages, printed out on a multilogger, and simultaneously punched on a tape. The tape can be analyzed directly, or the data can be punched on cards for summarization and analysis. Detailed measurement of other heat-flow elements in forest openings also await development of this data logger.

Cooperation--This study has been made possible by the cooperation of the Weather Bureau in servicing and operating our wind recording instruments at their Blue Canyon Station.

Hydrologic Process and Erosion Measurements, Onion Creek Watershed (Study No. 1-8)

We are studying hydrologic processes--what happens to snow and rain--with differences in the amount of snow and rain received, and with differences in vegetation, soil moisture, and heat and wind at two sites: logged and unlogged.

Objectives--To obtain quantitative estimates of interception loss, snow accumulation and melt, summer soil moisture storage and loss, and erosion in a logged and unlogged area.

Methods--An area of forest in Onion Creek watershed was logged over in August, 1957. We were unable to make any pre-logging measurements of the hydrologic processes in the area, so we were forced to use a similar unlogged area as a control. We measured early fall increments to soil moisture as an index to interception loss, snow accumulation and melt, and are now measuring summer soil moisture loss. Erosion is being measured at transects on the logging roads, skid trails, and channel crossings.

The effects of the logging on snow accumulation and melt are indicated by the following summary of the results:

Condition	Water Equivalent -- Inches					
	Jan. 17	Feb. 28	Apr. 25	May 6	May 27	June.20
Forest Uncut	10.0	27.5	51.2	43.5	24.6	1.7
Forest Cut	13.0	33.1	58.3	48.4	23.2	1.1
Difference	+ 3.0	+ 5.6	+ 7.1	+ 4.9	- 1.4	-0.6

The differences are about as expected, for a conventionally logged area: more snow accumulation in the cut area, then more rapid spring melt.

Plans--We intend to carry on the study through the winter of 1958, until the order of magnitude of the effects of this rather light cut can be appraised. Brush areas will be chosen and pretreatment measurements of snow and soil moisture started this summer.

Basic Meteorological and Snow Measurements, Teakettle Experimental Area (Study No. 1-9)

Objectives--To provide continuous measurements at control sites of the meteorological elements and certain measurements of snow needed to:

1. Define the meteorology of several years before watershed treatment and after treatment in order to evaluate the effects of treatment.

2. Evaluate for the area the climatic characteristics that affect losses of water and timing of streamflow.

3. Appraise the meteorology of the years studied in terms of how representative they are of long-term conditions.

4. Provide meteorological data for immediate use in calibrating the Teakettle Experimental Watersheds. See Study 1-3.

Methods--Regular weather observations and measurements are being taken for us at a station near Wishon Dam(3 miles east of Teakettle Experimental Area) in the Kings River basin, elevation 6,520 feet. At eight nearby stations, snow evaporation measurements have been taken periodically since January 1957.

The regular weather measurements include air temperature, relative humidity, wind passage, depth of snow on ground, and general weather. Evaporation from a free-water-surface is also being measured.

Snow evaporation was measured in small plastic pans. The technique involved filling the pans with snow and weighing and re-weighing at approximately 12-hour intervals. The pans were set in forest stands, in openings of various sizes, and in a large exposed open area.

Results--Evaporation measurements from snow under the three conditions are summarized in Table 5, Appendix A, together with associated meteorological readings. Direct evaporation was rather small in the winter of 1957-58. In the large exposed open area, the total losses are estimated as 2.3 inches; in small forest openings, gains by condensation about balanced losses, estimated loss was 0.2 inches; and under forest canopies, a net gain of 2.2 inches was estimated for the year. Seasonally, only during a dry spell from late February to April did significant evaporation occur from snow even in the open.

Plans--Meteorological measurements are needed for at least one more year - until such time as adequate correlations with long-term weather stations can be established. Another year's data on evaporation from snow is also planned.

Cooperation--The cooperation of the Pacific Gas and Electric Company has made this study possible. Their participation in the work is appreciated.

Water Yield (Study No. 1-10)

When is water yielded, and in what amounts, from each facet of each watershed of the State?

Objectives--First, to determine the relationship of the amount and timing of Sierra streamflow to watershed and meteorological variables; and

Second, to apply these relationships in delineating areas in the State from which certain amounts of water are derived at certain times.

Methods--The approach is statistical; multiple covariance analysis will be used to relate water yield to its causes. Water yield will be expressed separately by months of the year. The "causes" evaluated will index the physical variables of water supply, storage, wastage, and delivery.

Plans--To complete the first analysis by January 1, 1959.

Heat Equivalent and Snow in Openings and on Forested Slopes (Study No. 1-11)

How do we develop methods of improving water yield? The trial and error method is out. Too many forest conditions exist, too many thousands of trials could be made and still many questions remain unanswered. We seek more universal measure of forest conditions than the usual ones of forest type and age.

Objectives--To find relations between forest conditions on slopes and the heat equivalent and snow accumulation and melt on these slopes, and to select openings and forest conditions which will prove useful for the conduct of other studies being planned, particularly studies of snow physics, wind effect on snow, and summer and winter water losses.

Methods--Fifty-eight snow courses, with about 24 points in each, were selected in the summer of 1957, near the Central Sierra Snow Laboratory. Snow accumulation at each of the points was measured about monthly during the winter of 1957-58 and about twice monthly during the 1958 spring melt season. The courses were selected to have all combinations of possible conditions of slope, aspect, sizes of openings, and densities of forest stands. To do this, we tried to find courses to fill each blank of the "Selection Table" shown in Table 6, Appendix A. We tested the ones selected to see that there was no hidden correlations of slopes and

and forest conditions with sizes of trees, elevation, and sequences of sampling. The courses selected do not fill every blank, but a good distribution was obtained.

At each snow course a grid of points was randomly located, with the grid arbitrarily oriented north-south and east-west. At forest openings we spaced the points so as to have about one-third of the 24 points within the opening and two-thirds in the adjacent forest. A typical opening and the sampling points are shown in Figure 3.

We intend to analyze snow accumulation and melt at each of the snow measurement points, characterizing the forest in so far as possible by some measure of the energy received at the point, and by measurements of the forest density in the solar paths. Ashton Codd's pinhole camera canopymeter 3/ has been adapted to photograph the canopy in about 80 percent of the hemisphere in a single photo. These photos give a permanent record of the canopy (figure 4), thus facilitating determination of several forest variables.

Results--Records at all courses have been taken starting in early winter and continuing still at the time of this report. Essentially complete records were obtained despite last winter's heavy snow. Maximum depth at the Headquarters Station was 213 inches, Figure 6, Appendix B. Maximum depths measured at any point in any course was 432 inches, with 230 inches of water equivalent (bottom was not reached). First year results have not yet been completely summarized.

Our attempt to develop a "dirt cheat" radiometer to measure heat inflow and outflow at the snow measurement points has not been successful to date. Heat sensitive paper fails to respond to low heat values over long periods of time. Moth balls gave difficulties of water absorption. A new device, developed from suggestions from several sources, including a contact with the National Bureau of Standards and Bert Goodell of the Rocky Mountain Station, seems promising. It involves a system in which the heat

---

3/ Personal correspondence with Ashton Codd, Soil Conservation Service, Montana State University, Bozeman, Montana.

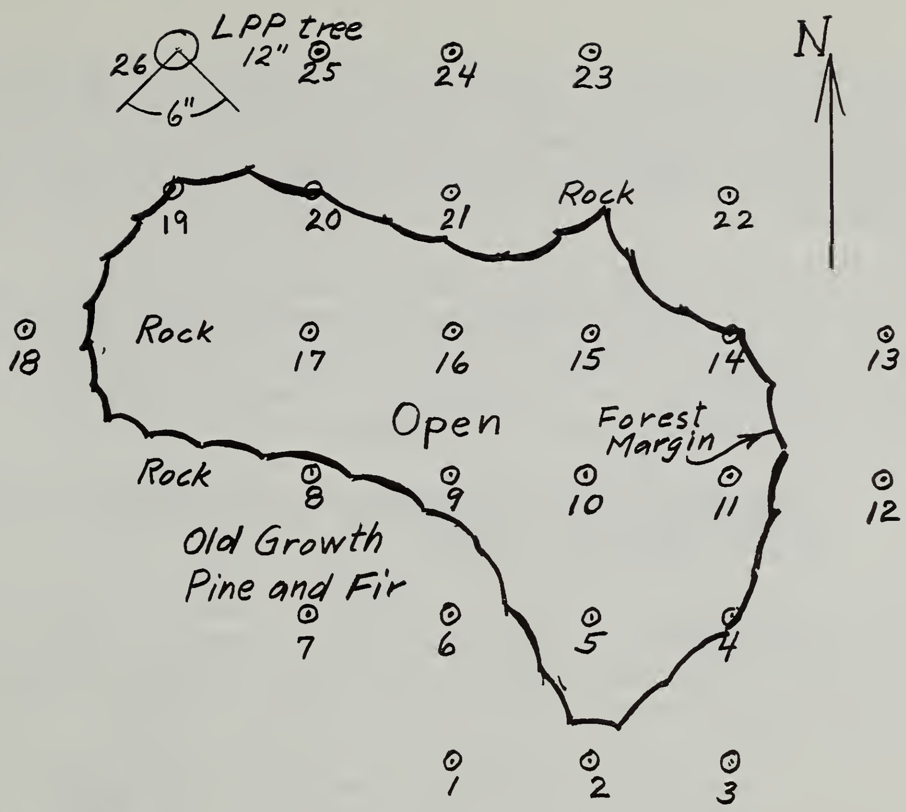


Figure 3.--Map of forest opening No. 27, showing snow sampling grid, Central Sierra Snow Laboratory, 1957-58.

Figure 4.--Photocanopy picture taken with photocanopy for point No. 10, opening No. 27, Central Sierra Snow Laboratory.

absorbed by a plate controls the charging of a capacitor. The rate of the charging capacitor is a measure of the heat absorption. The discharge from the capacitor, amplified by transistors, operates a relay counter which tallies the radiation.

Plans--We plan to continue the study for at least 1 more year. Canopy photos will be taken this summer. Data will be summarized and the first paper covering the results will be presented at the Society of American Foresters Meeting in Salt Lake City in September 1958.

Streamflow and Sedimentation Measurements, Castle Creek (Study No. 1-12)

Objectives--First, to obtain streamflow and sediment measurements from a watershed during a stable period of watershed conditions against which any changes in streamflow or sedimentation following some treatment might be evaluated.

a. Changes in suspended sediment and streamflow following the logging off of about 2 million board feet, scheduled to start in August, 1958.

b. Changes in suspended sediment following the construction of the new U. S. 40 "Freeway" in the basin above the gage, planned to start in about 2 years.

Second, to record the effect of any treatment which we may devise on streamflow and sedimentation, such as timber cutting, brush removal, wet meadow drainage, beaver dams, or snow drift control with fences, and

Third, to provide a record against which methods of streamflow forecasting from meteorological and snow records can be tested.

Methods--Streamflow from the 3.96 sq. mi. Castle Creek drainage basin is measured continuously by means of a 2-foot, 149° V-notch during low flows and a 12-foot Parshall flume during high flows (Table 2, Appendix A). Sediment is measured as suspended sediment, using the D-48 depth-integrating sampler. Samples are taken in the Parshall flume section and just above this flume.

Results--Streamflow at 8:00 a.m. of each day, and maximum for the period June 1, 1957 to June 30, 1958 are shown in Figure 7, Appendix B. Mean daily flows may be approximated from these data. For the spring melt period mean daily equalled about 1.1 times the 8:00 a.m. reading.

Suspended sediment data have not yet been worked up. At most times the water is practically clear.

Plans--We plan to intensify the measurements of suspended sediment in preparation for evaluating the logging that will start soon. Our plans include an additional sampling station above the area to be logged, and in intermediate station above the proposed freeway route, but including some of the logged area. Soil moisture storage, snow accumulation, and other hydrologic process measurements will be made in the logged areas and in comparable unlogged areas. Fortunately we have, as part of Study 1-11, 1 year of pre-logging measurements of snow accumulation and melt at several areas which will later be logged. These will furnish good tests of logging effects.

Winter Evapotranspiration in Relation to Forest and Terrain Characteristics (Study No. 1-13)

Objectives--First, to determine how winter evapotranspiration from forest and mountain snowpacks is affected by: elevation, slope and aspect, forest type, crown density, size of opening, wind, air temperature and humidity, and radiation, and

Second, to determine possible forest management methods of minimizing winter evapotranspiration losses.

Methods--Winter water losses are very difficult to evaluate, so we are making separate evaluations of the processes--evaporation from snow, interception of snow and rain by the tree canopies, and transpiration by the trees. This year's work was confined to the first two. We have not yet developed a satisfactory method of measuring winter transpiration.

Evaporation from snow is being measured with plastic pans, filled with snow (natural surface upward) and put flush with the snow surface in openings and under forest canopies.

Interception of snow by the trees is being approximated in two ways:

1. By measurements of soil moisture under tree

canopies and in the open after the first fall rains or snow melt.

2. By measuring differences in snowfall under trees and in the open, using pie tins placed out at the start of snowfall.

A special study of condensation of water on late spring snow patches has been started using the plastic pans.

Results--Evaporation from snow surfaces was slight at the Central Sierra Snow Laboratory. February to June loss in a small forest opening (about half the height of the trees across) totalled 0.8 inches; loss under a forest canopy was 0.3 inches. The summary by months is shown below:

Month	Evaporation from snow--inches	
	Under Forest Canopy	In Small Opening
February	0.017	0.089
March	0.048	0.184
April	0.358	0.495
May	-0.036	0.108
June	-0.052	-0.030
Total	0.335	0.846

In the latter part of May measurements were taken three times per day. Evaporation occurred during the Noon until 4:00 p.m. period, then condensation took place during the period 4:00 p.m. to 8:00 a.m., and continued in the 8:00 a.m. to Noon period.

The effect of wind on evaporation and condensation at several parts of openings was studied. The part of a forest opening exposed to the wind (the north and west margins) had excess evaporation on days in which evaporation was general, and excess condensation on days when condensation was general. Other data have not yet been summarized.

Plans--Continue the snow evaporation and interception study another year, taking measurements at many different sites. Start preliminary measurements of transpiration, using sonic flowmeter, radio-active tracers, heat flux or other suitable method.

Heat Balance Components in Forests and Openings (Study No. 1-14)

Objectives--First, to amplify the present knowledge of the heat flow between the ground, snow, air, and forest; and

Second, to compare these same heat flow components with those occurring under various terrain and forest conditions in or near the Laboratory.

Methods--Starting in early winter of 1958 we will examine each of the heat balance components in a relatively open site near the headquarters--the control site--and alternatively at 4 openings in the forest within the Castle Creek Basin. Two of these sites are on slopes of the lower valley where they are exposed to the snow-bearing winds; the other 2 are on slopes of the upper valley where they are protected from the same southwest winds. Heat flow components will be measured and recorded using the data-logger. See Study 1-6.

Results--Some preliminary tests at the headquarters site have been made on penetration of radiation into the snowpack using the new Gier-Dunkle Solarimeter. Penetration of heat increased with density of the pack. This may have important implications in explaining snow melt.

The forest sites have been selected and cleared of trees. No data have been collected.

Plans--Take observations for 1 year and analyze the data before proceeding.

Evaluation of Summer Evapotranspiration in Relation to Forest Sites (Study No. 1-15)

Water stored in the soil at the end of summer is water saved. That much less water need be supplied to the soil before rain or snow melt again contribute to streamflow. Hence, summer soil moisture losses is important in water yield.

Objectives--To determine the relationship between forest site characteristics and (1) soil moisture storage capacity, and (2) summer soil moisture loss. To determine the relation of soil moisture loss to soil characteristics, including soil moisture storage. To determine the microclimate elements that can be related to or used to estimate soil moisture loss for various sites.

Methods--Soil moisture storage and summer soil moisture loss is being measured at some 45 different sites at the Central Sierra Snow Laboratory basin. These sites have been selected so as to have wide differences in slope, vegetation, and soil type. The four major soil types found in the basin (4), are being studied.

Summer losses are being determined as the difference between moisture stored in the soil at field capacity, soon after the snow disappears in spring, and moisture left at the end of the summer (corrected for any summer rain). In 1957, moisture was measured by weighing and drying; this year we will use the radio-active soil moisture probe and scaler to measure soil moisture directly.

Results--Field capacity measurements were made at some 75 sampling sites in 1957. Summer's end moisture was obtained at only a few of these--the fall rains came early and heavy, before we got the samples. (This year we will take measurements throughout the summer, using neutron probe and scaler). First results from data obtained in 1957 have been summarized. Within forest stands on a Lytton soil, the soil moisture losses ranged from 6.3 inches to 9.7 inches, where the soil ranged from 2 to 5 feet deep. The data are given in Table 7, Appendix A.

Plans--To continue the study through this summer. To explore the possibility of extending the study to sampling the summer soil moisture losses under the major soil and vegetation types of the snow zone of the state.

Swain Mountain Snow Studies (Study No. 1-16)

Studies of the silvicultural management of old-growth red fir for timber production are under way at the Swain Mountain Experimental Forest (figure 1). We ask what are the effects on snow and water yield.

Objectives--To test the effects of the various ways of cutting the forests upon snow accumulation, snow melt, and soil moisture relations. Cut and uncut stands of old-growth red fir will be compared. The tests will serve as guides to choices of cutting methods for maximizing water yield.

Methods--We are measuring snow accumulation, snow melt, and soil moisture storage and losses at selected transects of forest stands for a calibration period of 1 or 2 years before the cutting begins. After the stands

are cut, we will continue the measurements for a period of several years to evaluate the effects of the cutting.

In 1957-58 snow depth and water equivalent have been measured monthly at seven snow courses. Six of these were established in October, 1957 so as to extend from areas to remain uncut into areas to be cut in the summer of 1958. The other course, Swain Mountain No. 2 was established in 1956 and will continue to be measured as a control. The six snow courses are located in two cutting areas, an area to be strip-cut and an area to be block-cut.

Results--The results for the 1957-58 snow season are summarized in Table 8, Appendix A. Some clues to the effects of cutting are indicated by transect A61 to A65, which was selected so as to cross a 300 foot opening. The results are shown in Figure 8, Appendix B. At the time of the maximum snow pack, there was about 20 inches more water in the adjacent forest. That 5 to 10 inches of this was "stolen" from the forest directly to the leeward (the northeast) is strongly indicated by the data. Note that on June 4, snow was left only in the immediate shade at the south half of the opening.

Soil moisture storage has been determined and photocanopy pictures (See Study 1-11) taken for areas to be logged this summer. Photocanopy pictures for a point in a forest opening is shown in Figure 4.

Plans--To continue the snow and soil moisture measurements of the courses already chosen and to select a course in an area where a narrow road will be constructed within the next 2 years, so as to test the effects of narrower strips than those included in the cutting plans.

Cooperation--Our Division of Forest Management Research is cooperating by taking the winter snow measurements.

Sagehen Cooperative Study of Streamflow, Sedimentation, and Fish Habitat (Study No. 1-17)

The University of California, Department of Zoology, has for the last 6 years conducted a study of fish population, fish habitat and related studies on a segment of Sagehen Creek (Figure 1 and Table 2, Appendix A).

Figure 5.--Sagehen Creek streamgaging suspended sediment station, Truckee River Basin, California.

Objectives--To extend the studies at Sagehen Creek to the effects of streamflow and sedimentation on fish populations. To evaluate the effects of forest, brushland, and other land treatments on streamflow, sedimentation, and fish habitat and populations.

Methods--The basic methods involve measurements of streamflow, sedimentation (figure 5), and fish life over a period of time; the development of a calibration so that these might reasonably and with statistical confidence be predicted in future time; then the application of treatments to the watershed and its evaluation will follow.

An evaluation will start this summer of the effects of a conversion of about 400 acres of brush to a pine plantation. A bulldozer is being used to clear and windrow the brush; the area will be planted to pine. We are making hydrologic process evaluations similar to those of Study 1-9, and the effects on streamflow and sedimentation may be detectible though no calibration analysis has been made.

Results--Neither the streamflow nor the sediment data have been analyzed yet.

Plans--Continue the evaluation of the hydrologic processes, particularly the summer soil moisture losses under the treated and untreated areas. Continue measurement of streamflow and analysis of sediment samples.

Cooperation--The University of California, Department of Zoology, is cooperating in the study by taking samples of suspended sediment for our analysis. The U. S. Geological Survey is taking the streamflow measurements. The Tahoe National Forest is applying the treatment--clearing the brush and planting.

Erodibility of California Wildland Soils, Relation to Sedimentation (Study No. 1-18)

Objectives--To develop and test indexes of the erodibility of the soils of the mountains and foothill zones of California so that:

First, erosion, sediment transport, and sediment deposition from the watersheds of the state may be better predicted;

Second, the influence of climate, watershed physiography, and land use on sedimentation may be better evaluated; and

Third, management decisions which are influenced by sedimentation problems may be more rationally made.

Methods--The method is statistical, relating measured sediment deposition and suspended sediment measurements from whole watersheds to the soil erodibility, the watershed characteristics, and the climatic causes of sedimentation.4/ Sedimentation for about 75 watersheds of northern and central California have been worked up. Soil samples are being taken of the major soil-geologic types in three separate areas of the state--the North Coastal zone, the Sierra-Cascade zone, and the Central Coastal zone.

Results--The watersheds for which suspended sediment and reservoir deposition measurements have been received are listed in Tables 9 and 10, Appendix A. Additional knowledge of sedimentation measurements of northern and central California is solicited.

Plans--Test the relationships this year before carrying the study further.

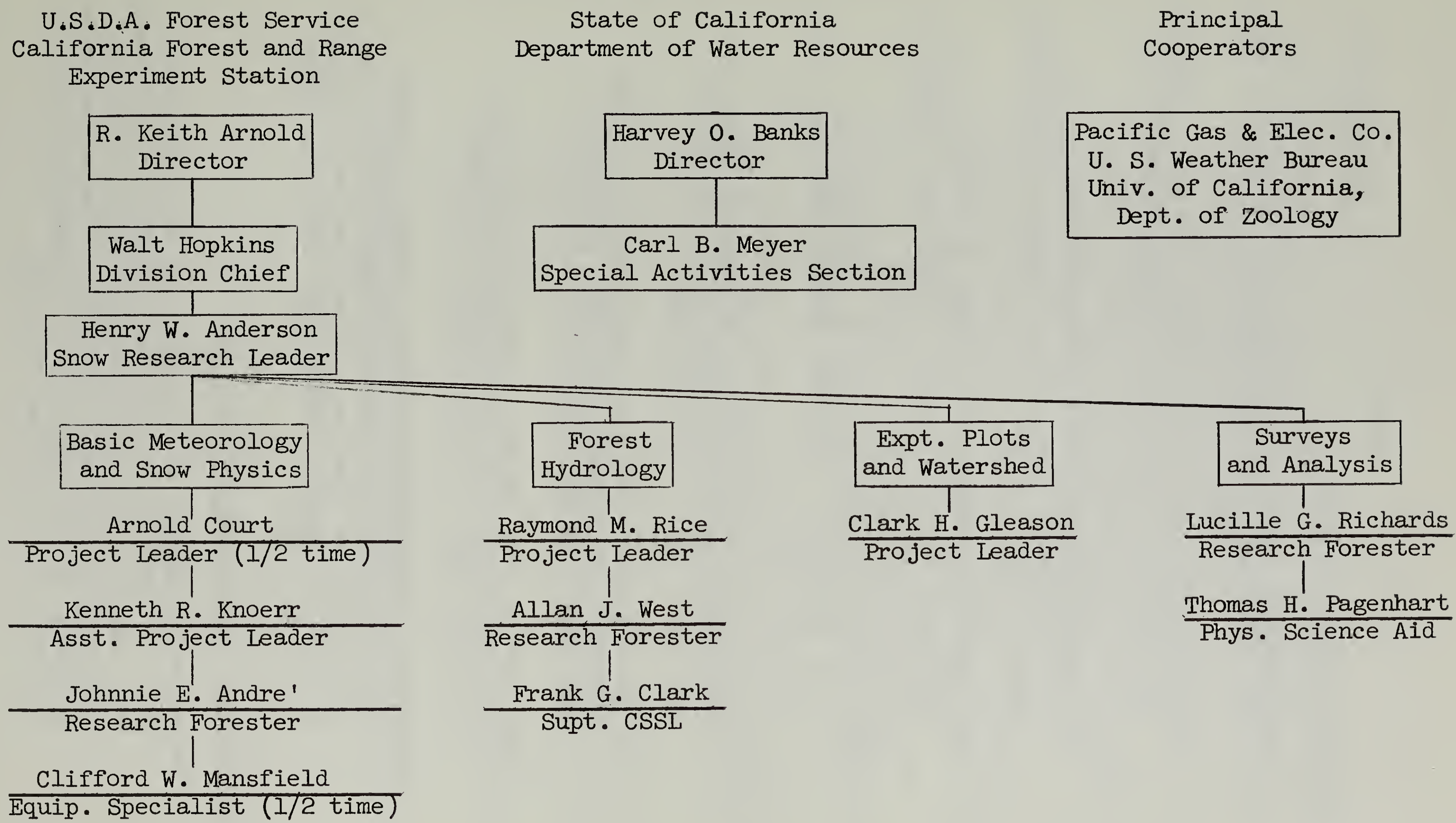
ORGANIZATION

The organization of the California Cooperative Snow Management Research is shown in the following chart. In all, 10 technicians are working directly on the project, 2 only half time. About an equal number of forestry aid and other assistants help keep the project running.

4/ See reference (3) in the section on Reports.

ORGANIZATION CHART - CALIFORNIA COOPERATIVE

SNOW MANAGEMENT RESEARCH 1958-59



Special Services: C. M. Walker, Editor; Wm. O'Regan, Statistician;
R. M. Miller, Data Processing
Admin. Services: F. W. Bacon, Chief, Divn. Station Management

REPORTS

Published (Copies attached)

1. "Anti-freezing hoods for V-notch weirs" by Carl O. Johannessen. Jour. Forest. 55(8):590, 1957

2. "Operation Wet-Blanket gets underway" by H. W. Anderson, Abstracted in Trans. Amer. Geophys. Union 38 (3): 414, 1957

3. "Relating sediment yield to watershed variables" by H. W. Anderson. Trans. Amer. Geophys. Union 38(6): 921-924, 1957

4. "Soil vegetation survey of a Central Sierra Snow Zone watershed" by R. E. Nelson. CF&RES Misc. Paper 21, 43 pp illus. Dec. 1957

5. "Snow on forested slopes" by H. W. Anderson and T. H. Pagenhart. 25th Ann. Western Snow Conf. Proc. pp 19-23, 1957

6. "Wind direction during snowfall at Central Sierra Snow Laboratory" by Arnold Court. 25th Ann. Western Snow Conf. Proc. pp 39-43, 1957

7. "New meteorological and snow studies in the Central Sierra" by K. J. Walsh, 25th Ann. Western Snow Conf. Proc. pp 43-45, 1957

8. "Snow surveys from the snow surveyor's side" by P. J. Wyckoff, 25th Ann. Western Snow Conf. pp 57-59, 1957

9. "Watershed management--an annotated bibliography of erosion, streamflow, and water yield publications by the California Forest and Range Experiment Station" by Clark H. Gleason, CF&RES Tech. Paper 23, 79 pp, illus. Jan. 1958

Manuscripts Accepted for Publication

1. "Watershed management in the snow zone of California" by H. W. Anderson. Describes cooperative snow management research program of the Experiment Station in cooperation with State Department of Water Resources. To appear in the Trans. First Intersociety Conf. on Irrigated Agriculture and Drainage.

New Manuscripts

1. "Snow management research in High Sierra Range" by R. M. Rice. Presented at Range Management Society meeting in Sacramento. Submitted for publication in Journal of Range Management.

2. "Forest shade related to snow accumulation" by H. W. Anderson, R. M. Rice, and A. J. West. Presented at Western Snow Conference. To be submitted to them for publication in Proceedings, 1958.

3. "Selection of best snow course points" by Arnold Court. Presented at Western Snow Conference. To be submitted to them for publication in Proceedings, 1958.

4. "Progress in snow management research in California" by H. W. Anderson. Presented at Western Snow Conference. To be submitted to them for publication in Proceedings, 1958.

5. "Forest effect on floods in Northwest" by H. W. Anderson and R. L. Hobba. Presented at Amer. Geophys. Union meeting, Washington D. C. To be submitted for publication in Transactions.

6. "Rain-snow-flood sources meteorologically defined" by H. W. Anderson. Presented at the Amer. Meteorol. Society meeting in Logan, Utah. To be submitted for publication in Bulletin.

7. "Evaporation from snow" by A. J. West. To be published as a Station Research Note.

8. "Forest effects on snow--a review" by A. J. West and T. H. Pagenhart. To be published as a Station Paper.

APPENDICES

A. TABLES

B. FIGURES

C. SPECIAL REPORT

"Sedimentation of small experimental watersheds"

D. REPRINTS

APPENDIX A

TABLES

Table 1.--Forest and slope characteristics for elevations above 5,000 feet on the west side of the Sierra Nevada Mountains Latitudes 36°57-1/2' to 39°57-1/2'

ITEM	ACREAGE	PERCENT OF AREA
FOREST OPENINGS		
Less than 132 ft. across1/	1,953.5	22.1
Less than 132 ft. across2/	7.3	.1
132-264 ft. across	107.8	1.2
264-528 ft. across	306.8	3.5
528-1056 ft. across	481.6	5.4
> 1056 ft. across	4,423.5	50.0
Total	7,280.5	3/ 82.3
FOREST DENSITY		
0-14 percent	5,327.0	60.3
15-39 percent	1,603.5	18.1
40-69 percent	1,521.5	17.2
70-100 percent	388.0	4.4
Total	8,840.0	100.0
CONDITIONS IN OPENINGS4/		
Brush	1,649.6	31.0
Grass-Herb	675.7	12.7
Rock-Ground	2,498.9	46.9
Trees	218.4	4.1
Other	284.4	5.3
Total	5,327.0	100.0
SLOPE		
0-10 percent	-	14.9
11-20 percent	-	37.1
21-30 percent	-	17.2
31-40 percent	-	14.9
41-50 percent	-	8.2
51-60 percent	-	2.7
61-70 percent	-	2.3
over 71 percent	-	2.7
Total	-	100.0
SLOPE DIRECTION		
North	-	18.1
East	-	17.2
South	-	29.4
West	-	34.8
Level	-	.5
Total	-	100.0

1/ Collectively determined.
2/ Individually measured openings consisted of roads and streams.
3/ Percent of total area.
4/ Openings greater than 132 feet across.

Table 2.--Experimental watersheds, measurement devices and results 1956-57

Name		Major River Basin	Drainage Area	Elevation	Weir Type & Capacity		Reservoir Capacity	Sedimentation
			Sq. mi.	Ft.			A.F.	A.F./Sq. mi.
Teakettle	No. 1	N. Fk. Kings	0.77	6410-8000	5'90°V) 2x6' Cip.)	200 cfs	0.351	0.058
	No. 2	N. Fk. Kings	0.85	6920-8160	5'90°V) 2x6' Cip.)	200 cfs	0.106	0.041
	No. 2a	N. Fk. Kings	0.27	6890-7940	5'90°V	135 cfs	0.066	0.030
	No. 3	N. Fk. Kings	0.86	6708-8100	5'90°V) 2'x6'Cip.)	200 cfs	0.117	0.013
	No. 7	N. Fk. Kings	1/ 0.11	6800-7100	2'90°V	22 cfs	0.204	0.211
Onion Creek	No. 1	N. Fk. American	0.19	6160-7300	3'120°V	70 cfs	0.113	2/
	No. 2	N. Fk. American	0.48	6150-7600	4-1/2'120°V	160 cfs	0.261	2/
	No. 3	N. Fk. American	0.73	6300-7896	Section	-	-	3/
	No. 5	N. Fk. American	0.39	6560-8383	4'120°V	140 cfs	0.177	2/
Castle Creek	No. 1	So. Fk. Yuba	3.96	6865-9103	12' Parshal, 149°V,	300 cfs 100 cfs	None	3/
Sagehen Cr.	No. 1	Truckee	11.1	6300-8000	Variable V Section,	500 cfs	None	3/

1/ Subject to revision after final field check of areas.
2/ Sediment accumulation started 1957-58.
3/ Watershed has no sediment basin. Suspended sediment samples are periodically taken.

Table 3.--Meteorological and snow records taken and status of data processing, 1957-1958

STATION	ELEMENT	INSTRUMENT	FREQUENCY OF READINGS	PERIOD COVERED		PROCESSING STATUS
				FROM	TO	
H Headquarters, CSSL	Precipitation	Recording gage	Continuous	10-21-57	6-30-58	All records checked. Tabulated by hours.
	Snowfall	Snow Board	Daily			Not tabulated.
	Acc. Snowfall	Special Course	Daily, 0800	12-11-57	-	Plotted on graph.
	Air Temperature Max. & Min.	Thermometers	Daily, 0800	10- 1-57	6-30-58	Plotted on graph.
	Max. & Min.	Thermograph	Continuous	10- 1-57	6-30-58	Plotted on graph.
	Current	Thermometers Thermograph	Daily, 0800	10- 1-57 10- 1-57	6-30-58 6-30-58	Not tabulated.
	Air Moisture	Psychrometer	Daily, 0800	10- 1-57	6-30-58	Not tabulated.
	Air Moisture	Hygrograph	Continuous	10- 1-57	6-30-58	Not tabulated.
	Atmospheric Pressure	Merc. Barometer	Daily	10- 1-57	6-30-58	Not tabulated.
	Atmospheric Pressure	Microbarograph	Continuous	10- 1-57	6-30-58	Not tabulated.
	Atmospheric Pressure	Barograph	Continuous	10- 1-57	6-30-58	Not tabulated.

Table 3.--Continued

STATION	ELEMENT	INSTRUMENT	FREQUENCY OF READINGS	PERIOD COVERED		PROCESSING STATUS
				FROM	TO	
H Headquarters, CSSL	Wind Direction and Speed	Esterline-Angus Recorder	Continuous	10- 1-57	6-30-58	Tabulated by hours & combined with precip-itation.
	Radiation	Pyroheliometer and Radiometer	Continuous	12- 6-57	6-30-58	Partly tabulated.
M Upper Meadow Castle Creek	Precipitation	Recording gage	Continuous	4-19-58	6-30-58	Not tabu-lated.
	Snowfall	Snow Board	Weekly	10- 7-57	6-26-58	Not tabu-lated.
	Acc. Snowfall	Snow Course	Weekly	12-10-57	6-26-58	Not tabu-lated.
	Air Temperature Max. & Min.	Thermometers	Weekly	10- 7-57	6-26-58	Not tabu-lated.
	Max. & Min.	Thermograph	Continuous	10- 1-57	6-30-58	Not tabu-lated.
	Current	Thermograph	Continuous	10- 1-57	6-30-58	Not tabu-lated.
	Air Moisture	Hygrograph	Continuous	10- 1-57	6-30-58	Not tabu-lated.

Table 3.--Continued

STATION	ELEMENT	INSTRUMENT	FREQUENCY OF READINGS	PERIOD COVERED FROM	PERIOD COVERED TO	PROCESSING STATUS
O Onion Creek	Precipitation	Recording gage	Continuous	10-10-57	6-30-58	Not tabulated.
	Snowfall	Snow Board	Weekly	12-16-57	6- 4-58	Not tabulated.
	Acc. Snowfall	Snow Course	Weekly	12-23-57	6- 4-58	Not tabulated.
	Air Temperature Max. & Min.	Thermometers	Weekly	10-10-57	6-25-58	Not tabulated.
	Max. & Min.	Thermograph	Continuous	4-16-58	6-30-58	Not tabulated.
	Current	Thermograph	Continuous	4-16-58	6-30-58	Not tabulated.
	Air Moisture	Hygrograph	Continuous	4-16-58	6-30-58	Not tabulated.
R Ridge	Precipitation	Storage gage	Weekly	11- 8-57	6-25-58	Not tabulated.
	Snowfall	Snow Board	Weekly	11-27-57	6-25-58	Not tabulated.
	Acc. Snowfall	Snow Course	Weekly	12- 9-57	6-25-58	Not tabulated.

Table 3.--Continued

STATION	ELEMENT	INSTRUMENT	FREQUENCY OF READINGS	PERIOD COVERED FROM	PERIOD COVERED TO	PROCESSING STATUS
Onion Creek Major	Acc. Snowfall	Snow Course	Weekly	1- 6-58	5-28-58	Not tabulated.
Minor	Acc. Snowfall	Snow Course	Weekly	1- 6-58	5-28-58	Not tabulated.
L Mt. Lincoln	Atmospheric Pressure	Barograph	Continuous	11-25-57	3-15-58	Records not processed because of icing conditions
	Air Temperature					
	Max. & Min.	Thermograph	Continuous	None		
	Current	Thermograph	Continuous	None		
	Wind Speed and Direction	Esterline-Angus Recorder	Continuous	10-24-57	3- 8-58	
Blue Canyon	Precipitation	Recording gage (from W. B.)	Continuous	10- 1-57	6-30-58	Hourly tabulation made by W. B. combined into monthly summary.
	Wind Speed and Direction	Esterline-Angus Recorder	Continuous	10- 1-57	6-30-58	
Wishon Dam	Air Temperature					Tabulated and some months have been compared with Grant Grove, Huntington Lake and Big Creek PH #1
	Max. & Min.	Thermometers	Daily, 0745	10- 1-57	6-30-58	
	Max. & Min.	Thermograph	Continuous	10- 1-57	6-30-58	
	Current	Thermometers	Daily, 0745	10- 1-57	6-30-58	
	Current	Thermograph	Continuous	10- 1-57	6-30-58	
	Air Moisture	Psychrometer	Daily, 0745	10- 1-57	6-30-58	

Table 3 .--Continued

STATION	ELEMENT	INSTRUMENT	FREQUENCY OF READINGS	PERIOD COVERED		PROCESSING STATUS
				FROM	TO	
Wishon Dam	Air Moisture	Hygrograph	Continuous	10- 1-57	6-30-58	Not checked.
	Wind miles	Anemometer	Daily, 0745	10- 1-57	6-30-58	Not checked.
	Snow Evaporation	Snow Pans	Monthly	11- 5-57	5-16-58	Tabulated and summarized.
Swain Mountain	Acc. Snowfall	Snow Course	Monthly	1- 7-58	6- 4-58	Checked and plotted on graphs.

Table 4 .--Monthly climatic summary, Central Sierra Snow Laboratory, 1957-1958

MONTH	AIR TEMPERATURES							Total Wind	Total Precipitation	Cum. Daily Snow w.e.	Month-end Snow w.e.
	Averages			Extremes							
	Max.	Min.	Mean	Highest	Date	Lowest	Date				
	°C	°C	°C	°C		°C		Miles	-----	Inches	-----
July	23.0	4.7	13.8	27.0	5	+ 2.0	15	-	0.11	0.00	0.0
Aug.	22.2	3.0	12.6	26.9	2&3	- 3.0	30	-	0.00	0.00	0.0
Sept.	20.6	4.1	12.4	28.8	9	0.0	20	-	1.41	0.00	0.0
Oct.	8.9	-7.2	+ 0.8	14.8	9	- 4.5	7	2,479	4.63	2.01	0.0
Nov.	5.3	-5.4	0.0	15.0	25	-13.5	16	2,576	4.49	3.13	0.0
Dec.	4.1	-6.2	- 1.0	15.3	10	-15.8	22	2,639	11.52	9.04	13.6
Jan.	2.5	-8.1	- 2.8	8.6	8	-15.5	21	2,830	11.75	11.76	26.2
Feb.	2.7	-5.6	- 1.4	10.2	22	-15.5	27	2,489	20.66	16.08	38.0
March	+ 0.5	-9.3	- 4.4	8.5	20	-17.8	9	2,987	18.01	16.86	63.5
April	6.8	-5.2	+ 0.8	14.0	21&22	-12.2	23	2,467	8.52	10.99	71.0
May	14.3	-0.8	6.8	19.6	18	- 4.8	13	-	1.50	.30	33.5
June	15.4	+1.7	8.6	24.2	23	- 1.1	3	-	2.97	0.00	0.0
Total									85.57	70.17	
Average	10.6	-2.9	+ 3.9								

Table 5.--Evaporation from and condensation on snow, and associated meteorological conditions, Kings River area near Wishon Dam, California, 1957 and 1958

Date	Temperature: Max.	Temperature: Min.	Rel. Hum.[1]: Max.	Rel. Hum.[1]: Min.	Wind	Evaporation or Condensation[2]: In Forest[3]	In Opening[4]	In Open[5]
	°F		Percent		Mi./day	In./day	In./day	In./day
Jan 25, 1957	-	-	-	-	-	+.012	-.006	-.010
Nov 6, 1957	38	18	86	49	64.8	+.021	+.001	+.001
Feb 7, 1958	46	26	96	26	40.1	+.006	+.000	-.020
Feb 11, 1958	46	24	96	29	61.7	+.002	+.002	-.013
Feb 28, 1958	35	16	97	40	71.4	6/-.004	-.005	-.016
Mar 4, 1958	37	11	92	37	77.5	6/-.007	-.011	-.056
Apr 23, 1958	49	21	94	22	108.6	-.012	-.014	-.011
May 2, 1958	56	34	97	42	77.5	+.013	+.009	-.007
May 8, 1958	59	36	95	16	86.5	+.018	+.024	8/
May 16, 1958	65	40	94	15	93.2	+.017	7/+.014	8/
					Median	+.0098	+.0018	-0.0104
Estimated seasonal loss or gain Nov 1, 1957 - June 1, 1958						+2.2	-0.2	-2.3

1/ From Hygrothermograph, absolute accuracy low.
2/ Minus indicates evaporation; plus indicates condensation.
3/ Average Sta. No. 8 and 11.
4/ Median Sta. Nos. 5, 6, 7, 9, 10 & 12.
5/ Sta. No. 4.
6/ Median value used for one missing datum on Sta. 8.
7/ No snow at Sta. Nos. 6 & 7.
8/ Only patches of snow left, insufficient to sample.

Table 6.--Selected snow courses in forests and openings and their site characteristics, Central Sierra Snow Laboratory

Opening Size or Density Class[1]	N Az. 315-45° % Slope 15	N Az. 315-45° % Slope 30	E Az. 45-135° % Slope 15	E Az. 45-135° % Slope 30	E Az. 45-135° % Slope 60	S Az. 135-225° % Slope 15	S Az. 135-225° % Slope 30	S Az. 135-225° % Slope 60	W Az. 225-315° % Slope 15	W Az. 225-315° % Slope 30	W Az. 225-315° % Slope 60	Level % Slope 0-5
Forest Openings Courses												
1/2H to 1H	73M[2]	73M	76L	67M		73M	77L		74L	74L	62L	61L
1H to 2H	73M	74M	78L	72S		75S	67S		73M	63M		76L
2H to 4H	76L		75M				72M		75S			72S
4H		77S		75L		70L			63L			71M
Forest Density Courses												
20% to 50%	73M	75M	75S	77L		66L			73S	69M	74M	74M
50% to 80%	74M	72M	76L	70M	76L	75M	76L		74M	73M	76L	76L
80% to 100%		67M	67M	67M		78L	78M	76L	67L		67L	67L

1/ Openings are in ratios of diameter of opening to height of surrounding trees e.g.1/2H opening is one-half tree height across.

2/ The number is elevation of course in hundreds of feet, the letter is size of trees: L = large, over 100 ft. high, M = Medium, 60-100 ft. high, and S = Small, less than 60 ft. high.

Table 7 .--Soil moisture and summer soil moisture losses, Castle Creek Basin, 1957

Plot No.	Soil-Veg. Class[1]	Aspect	Slope %	Depth In.	Field[2] Capacity % wt.	Fall[2] Soil H_2O % wt.	Summer ET.[3] % wt.	Est. Vol. wt. (gm/cc)	Inches of soil Involved	Percent Soil Vol. less Rock	Inches Water Summer ET.[3]
A19	7112/3E-2	145°	24	0-3	39.2	13.5	25.7	1.2	3	86.4	0.80
	Y433/BC			3-6	39.8	14.0	25.8	1.2	3	86.4	0.80
	Lytton Soil,			6-12	40.3	14.5	25.8	1.2	6	86.4	1.60
	Small Pine			12-24	41.9	16.1	25.8	1.2	12	86.4	3.20
	20-50%										6.40
	density										
A55	7112/3E-1D	335°	13	0-3	46.1	20.2	25.9	1.2	3	84.2	0.78
	Y433/BC			3-6	46.4	20.4	26.0	1.2	3	84.2	0.79
	Lytton Soil,			6-12	46.7	20.6	26.1	1.2	6	84.2	1.58
	Small Pine			12-24	47.7	20.9	26.8	1.2	12	84.2	3.25
	20-50%			24-36	48.9	21.5	27.4	1.2	12	84.2	3.32
	density										9.72
A62	7112/5-1	195°	4	0-3	35.6	18.7	16.9	1.1	3	93.0	0.52
	OY222/CB			3-6	35.7	18.7	17.0	1.1	3	93.0	0.52
	Lytton Soil,			6-12	35.8	18.8	17.0	1.1	6	93.0	1.04
	Red Fir			12-24	36.0	19.0	17.0	1.1	12	93.0	2.08
	50-80%			24-36	36.3	19.1	17.2	1.1	12	93.0	2.11
	density										6.27
A71	7112/5-1D	125°	5	0-3	34.0	22.3	11.7	1.2	3	86.4	0.36
	Y411/6			3-6	34.0	22.0	12.0	1.2	3	86.4	0.37
	Lytton Soil,			6-12	33.9	21.7	12.2	1.2	6	86.4	0.76
	Red Fir			12-24	33.8	20.9	12.9	1.2	12	86.4	1.60
	80-100%			24-36	33.6	19.9	13.7	1.2	12	86.4	1.70
	density			36-48	33.5	18.9	14.6	1.2	12	86.4	1.81
				48-60	33.3	17.8	15.5	1.2	12	86.4	1.93
											8.53

1/ See Report (4) for fuller descriptions of soils and vegetation indicated by symbols.
2/ Non-rock fraction.
3/ Evapotranspiration from non-rock fraction, 98 days for A19, 85 days for A55, 78 days for A62 and 71 days for A71.

Table 8.--Swain Mountain snow studies--average water content

FOREST	POINTS	1958 DATE 1/6-7	2/6-7	3/4-5	4/9-10	5/1-2	6/4-5
		Inches					
Very dense Red Fir	A 1-15	5.4	14.6	20.8	35.6	30.3	4.5
Opening 1-1/2 H	A 16-21	8.3	22.5	30.8	47.4	39.6	3.9
Very dense Red Fir	A 22-33 & 58-65	4.9	15.2	20.5	33.2	28.8	2.2
Dense Red Fir	A 34-57	5.6	15.1	20.8	34.9	29.3	4.0
Small Openings	C 1,2,9,24 & 34	8.3	24.9	30.8	-	41.5	14.9
Open Old Red Fir	C All other	7.4	21.3	28.4	-	38.4	8.3
Old-Young Red Fir	D All D	6.7	19.7	29.0	-	40.1	11.2
Opening	Swain Mt. Course #2	7.1	20.3	26.2	45.8	32.5	No snow

Table 9.--Watersheds for which suspended load data are available, northern California, 1958

STREAM	STATION	WATERSHED AREA 1/	DATE	NO. SAMPLES
		Sq. mi.		
NORTH COAST AREA				
Klamath R.	Somes Bar	(8,480)	1955-56	12
Klamath R.	Seiaid Valley	(7,800)	"	4
Klamath R.	Klamath	12,100	"	4
Mad R.	Arcata	485	"	22
Trinity R.	Lewiston	727	"	19
S. F. Trinity R.	Salyer	899	"	4
Clear Cr.	French Gulch	115	"	16
Van Dusen R.	Bridgeville	214	"	17
Eel R.	Scotia	3,113	"	18
S. F. Eel R.	Miranda	547	"	11
Scott R.	Jones	662	"	4
Smith R.	Crescent City	613	"	4
Mad R.	Forest Glen	139	"	6
Cottonwood Cr.	Cottonwood	945	"	10
Russian R.	Ukiah	104	1952-55	636
NORTHERN SIERRA NEVADA				
Battle Cr.	Cottonwood	362	1955-56	10
Sacramento R.	Red Bluff	9,300	"	9
M. F. American R.	Auburn	619	"	8
Mokelumne R.	Clements	630	"	7
Cosumnes R.	McConnell	730	"	14
M. F. Feather R.	Sloat	836	"	6
Indian Cr.	Crescent Mills	746	"	7
S. F. American R.	Lotus	678	"	6
S. F. Yuba R.	Castle Cr.	4	1957-58	55
Truckee R.	Sagehen Cr.	11	"	14
SAN FRANCISCO BAY AREA				
San Francisquito Cr.	Stanford U.	37.7	1955-56	9
Walnut Cr.	Walnut Cr.	78	"	9
SOUTHERN COAST AREA				
Sespe Cr.	Wheeler	(50)	1955-56	9
Sespe Cr.	Fillmore	254	"	3
N. F. Matilija R.	Matilija	15.5	"	11
Ventura R.	Robles Dam	-	"	6

1/ Parentheses indicate area is rough estimate.

Table 9.--Continued

STREAM	STATION	WATERSHED AREA 1/	DATE	NO. SAMPLES
CENTRAL COAST AREA		Sq. mi.		
Cuyama R.	1	81	1941	7
"	2	410	"	12
"	3	804	"	17
"	4	912	"	12
Sisquoc R.	5	442	"	7
Santa Maria R.	6	1,638	"	18
"	7	1,763	"	16
Bradley Cr.	8	10	"	11
Ballinger Cr.	9	30	"	4
Tepusquet Cr.	10	13	"	3
Huasna Cr.	11	119	"	8
Alamo Cr.	St. Hwy. 166	89	"	6
Quatal Canyon Cr.	St. Hwy. 399	(30)	"	5
Piru Cr.	Hwy. Bridge	432	1932-35	18
Santa Clara R.	Saticoy Hwy. Bridge	355	1933-34	5
Sespe Cr.	Hwy. Bridge	254	1932-35	19

1/ Parentheses indicate area is rough estimate.

Table 10.--Watersheds for which reservoir sediment data are available, northern California, 1958

STREAM	STATION	AREA	PERIOD 1/ Length	PERIOD 1/ Year Measured
		Sq. Mi.	Years	
NORTH COAST AREA				
Forsythe Cr.	Ridgewood (Ukiah)	5.9	19	1949
James Cr.	Morris (Willets)	5.2	25	1949
Big Canyon Cr.	B. Canyon (Frntwn)	5.5	11	1945
Little Stoney Cr.	East Park Res.	101.5	35	1946
N. F. Jenney Cr.	Faulke Lake	.7	94	1945
Trib. Burch Cr.	Gerber (Corning)	.3	28	1945
Stoney Cr.	Stoney Gorge	199.0	17	1946
N. F. Cottonwood Cr.	Misselbeck (Redding)	12.0	25	1945
NORTHERN SIERRA NEVADA				
Trib. Cosumnes R.	Blodgett (Sacto.)	3.1	5	1946
N. Yuba R.	Bullards Bar.	480.0	19	1939
Bear R.	Combie (Auburn)	130.0	7	1935
Little Butte Cr.	Magalia (Chico)	8.2	28	1946
N. F. American R.	Onion Cr. (3 res.)	.2-.5ea.	1	1958
CENTRAL CALIFORNIA COAST RANGES				
Pacheco Cr.	North Fork	66.0	12	1951
N. F. Las Viboros	Hawkins	4.0	28	1940
Atascadero Cr.	Atasc. Park Lake	1.0	29	1947
Salinas R.	Salinas	111.0	12	1953
Santa Ynez R.	Above Gibraltar (4 res.)	16-205.0	1-26	1948
Triunfo Cr.	Lake Sherwood	16.0	33	1938
SOUTHERN SIERRA NEVADA				
Penny Cr.	Copperopolios	2.1	30	1945
N. F. San Joaquin R.	Crane Valley	54.5	45	1946
Shaw Cr.	Davis (Stockton)	7.9	28	1945
Tuolumne R.	Don Pedro (Modesto)	1,001.0	22	1945
Merced R.	Exchequer	1,027.0	19	1946
Trib. Mormon Slough	Gilmore (Bellota)	5.0	28	1945
Ten Mile Cr.	Hume	24.2	37	1946
S. F. Stanislaus Cr.	Ivons	40.0	16	1946
Trib. Johnny Cr.	McCarty	.41	7	1945
Mokelumne R.	Pardee (Lodi)	387.0	14	1943
Rock Cr.	Salt Spgs. Valley	20.3	63	1945
Bear R.	Upper Bear R.	28.5	45	1946
San Joaquin R.	Kerckoff #6	(905.)	16	1939
N. F. Kings R.	Teakettle (5 res.)	.1-.9ea.	18	1958
SAN FRANCISCO BAY AREA				
Laguna Cr.	Upper Crystal Spgs.	13.3	58	1935
Walnut Cr.	St Mary's	3.1	23	1951
Eleven Farm Ponds	Brentwood	.3ea.	8	1952

1/ Last year sediment measured.

APPENDIX B

FIGURES 6-8

APPENDIX C

SPECIAL REPORT

Sedimentation of Small Experimental Watersheds

Sedimentation of Small Experimental Watersheds

By H. W. Anderson

In 1938, the Teakettle Experimental Watersheds were established in the southern Sierras in the North Fork of the Kings River basin. A laboratory building was constructed at that time and five small forested watersheds were equipped with reservoirs to catch sediment and gages to measure streamflow. The laboratory was operated 2 years and then closed because of lack of funds. Since 1938, however, the reservoirs have caught sediment delivered from their watersheds, and the accumulated sediment in four of these has been measured from time to time. These measurements provide an opportunity to evaluate sedimentation in watersheds on which the timber will later be cut to pilot-test the promising methods of snowpack management. We need this evaluation because one objective of snow research is to learn how to improve water yield without excessively increasing sedimentation.

The Teakettle Experimental Watersheds are located in old-growth California red fir, at elevations ranging from 6,400 to 8,100 feet. Characteristics of these watersheds and experimental installations are summarized in Table 2, Appendix A.

Periodic sedimentation measurements for the Teakettle watersheds are given below, together with the average reservoir capacity and the average relative peak discharge (of the nearby Kings River) for each period. The sedimentation data were analyzed for two purposes: (1) to determine the mean annual sedimentation for each watershed and the effect of a small burn in No. 1, and (2) to test the degree of calibration achieved for detecting effects of future treatments on sedimentation.

Periodic sedimentation (sed.), capacity-watershed area ratios (c/w), and relative peak discharges, Teakettle Snow Laboratory[1]

Period (fall to fall)	Watershed[2] No. 1 Sed.	c/w	Watershed No. 2 Sed.	c/w	Watershed No. 2A Sed.	c/w	Watershed No. 3 Sed.	c/w	Relative peak discharges
	AF	AF/sm	AF	AF/sm	AF	AF/sm	AF	AF/sm	cfs/cfs
1938-40							.0026	.151	.709
1940-41							.0204	.138	1.124
1938-41					.0146	.270			.848
1941-48					.0084	.210	.0112	.089	.951
1938-48	.0271	.370	.0066	.126					.920
1948-51	.1100	.120	.0250	.059	.0320	.150	.0160	.029	1.224
1951-55	.0077	.002	.0080	.014	.0110	.090			.968
Mean per sq. mi. per yr.	.0371		.0102		.0140		.0115		

1/ The capacity-watershed area ratio c/w is the average capacity of the reservoir below spillway level in the period divided by the watershed drainage area (see Table 2, Appendix A). Relative peak discharge is the mean of the annual peak discharges of the period divided by the mean of the annual peak discharges for the 34-year period, 1922-55; discharges are of North Fork Kings near Cliff Camp, California.

2/ Small burn occurred in this watershed in 1943; the other are unburned.

For both purposes it was necessary to correct the periodic measurements of sedimentation for variations between periods in the relative discharges and in the trap efficiency of the reservoirs. To obtain a basis for the corrections, covariance analysis was used, with the periodic measurements of sediment being the dependent variable and the relative discharge in each period and the average capacity of the reservoir per unit of watershed area as the covariants. Watersheds 2, 2a, and 3 were used in this analysis; watershed 1 was not included because of the burn. For the 3 watersheds analyzed, the pooled within-regression was not significantly different from the individual regressions so the within-regression was used. It is:

$$\text{Sediment deposition (AF/sq.mi./yr.)} = 0.052\ \text{Relative discharge (cfs/cfs)} + 0.045\ \text{Capacity watershed ratio (AF/sq.mi.)} - 0.043$$

The standard error of estimate was ± 0.0046 AF/sq.mi./yr. and the regression explained 82 percent of the variance.

To determine mean annual sedimentation, the regression coefficients in the above equation were used to correct the periodic measurement to a uniform reservoir capacity (0.20 AF/sq.mi.) and to the long-term average relative peak discharge (1.00). When thus corrected, the sedimentation rates for the 3 watersheds were 0.016, 0.016, and 0.017 AF/sq.mi./yr. Thus the average annual sedimentation was nearly identical for the 3 watersheds, instead of varying by 35 percent as would have been interpreted from the means of the unadjusted periodic measurements. The fourth, watershed, in which a small burn of about 5 acres occurred in 1943, had about double the sedimentation of the others--0.036 AF/sq.mi./yr. These results indicate that sediment production from this type of watershed is very low when the forest is in virgin condition. The probability that fire increases sediment production is also indicated.

For the calibration analyses two methods were used. In the first analysis the individual regression equations relating periodic sedimentation to relative discharge and the reservoir capacity of each experimental watershed were used. The analysis indicated that if a treatment doubled the sedimentation it could be detected at odds of 19 to 1. In the second analysis, one of the experimental watersheds was used as a control. All periodic measurements of sedimentation were first corrected for differences in the reservoir capacities, using the regression coefficient for "capacity watershed rates" in the above equation. After being thus corrected, the relation of sedimentation from watershed 2 to that from 2a, for example, indicated that a treatment which would change sedimentation by as little as 1 percent could be detected on 19 to 1 odds. Thus, the calibration using sedimentation in one of the experimental watersheds as a control was much better than using the multiple regression as a control. Since only 3 or 4 periodic measurements of sediment were involved in both analyses, too much reliance should not be put on the exact quantities of these estimates. Measurement of sedimentation will continue during the streamflow calibration period.

PROGRESS REPORT, 1957-58

COOPERATIVE SNOW MANAGEMENT RESEARCH